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The ILLUMINATING ENGINEER

ELECTRICITY · ACETYLENE · OIL · GAS

Edited by LEON GASTER

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OFFICIAL ORGAN OF THE
Illuminating Engineering Society.
(Founded in London 1909.)

This number contains the Discussion on ***"The Lumen as a Measure of Illuminating Value,"*** which took place at the last meeting of the Illuminating Engineering Society (Founded in London 1909) on Tuesday, January, 16th, including the introductory contributions to the Discussion by ***Professor J. T. Morris*** and ***Mr. F. W. Willcox.***

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EDITORIAL.

Progress in 1916.

It is customary, at the beginning of a new year, to survey progress during the past twelve months. Owing to the war there is, however, little to record as regards developments in this country. The introduction of the Summer Time (Daylight Saving) Act, the darkening of the streets, the opportunities for economy in lighting—all these are matters of considerable interest, but they were dealt with in the discussion at the last meeting of the Illuminating Engineering Society, reported in our December issue.

We therefore confine ourselves to these few remarks on progress in 1916, in the sincere hope that before the end of another year the present world-conflict will be over, and illuminating engineering will have resumed its normal course.

The Lumen as a Measure of Illuminating Power.

The discussion on this subject at the last meeting of the Illuminating Engineering Society marks an important stage in our progress towards more scientific and definite methods of comparing sources of light. The origination of the Lumen, as a measure of flux of light, and as a basis of comparison of the illuminating power of sources is due to Professor A. Blondel, who first suggested the expression at the International Electrical Congress at Geneva in 1896. It is thus in no sense of "German origin," as one of our contemporaries incautiously suggests. (In any case, the comment is irrelevant. The only points of importance are the convenience and scientific value of the term, irrespective or its origin.) In France, on the other hand, whence this unit originated, the Société Française de Physique passed a resolution about three years ago, advocating rating on this basis; and in the United States, the Illuminating Engineering Society, which is representative of gas, electricity, and all other methods of lighting, formally adopted this method of rating at the Convention held last September. It was therefore natural that the matter should receive the attention of the Illuminating Engineering Society in this country.

The subject was dealt with in a preliminary discussion before the Society in May, 1914. Even at this time expert opinion was in favour of the proposition that illuminants should be rated primarily in Lumens. The contributions by Professor Morris and Mr. Willcox in this number state very clearly, what has been evident for some years, that the variation in existing methods of rating illuminants has led to endless confusion. The development of sources of light having widely different polar curves of light distribution, and still more the fact that by using appropriate globes or reflectors this distribution can be enormously varied according to our requirements, has made the practice of rating by candlepower in a single direction quite misleading. This method may have had a certain justification in days gone by, when all the lamps available had broadly the same distribution of light. It is no longer justifiable now.

These variations in distribution of light have only become generally apparent within the last few years, owing to the more general use of polar curves. They are not confined to any form of illumination; gas and electric lamps alike vary greatly in their distribution of light; and rightly so, because we could not otherwise obtain so easily the effects we desire in practice. It is, however, essential that these variations should be understood, recorded, and utilised, and we have therefore never failed to insist on the desirability of makers furnishing polar curves with their lamps. Now such curves are fairly familiar, though still not as generally employed as we could wish. The comparative novelty of the idea is shown by the fact that when Mr. J. G. Clark read a paper, describing their use before the London and Southern Junior Gas Association in 1910, several journals, in commenting on the proceedings, hinted that he was soaring above the minds of his audience, although they implied that an occasional "soar" was a necessary element in the propagation of new ideas. The arguments now brought forward in defence of the polar curve constitute a gratifying sign of progress, but we may say at once that none of the advocates of the Lumen have the least intention of advocating its disuse. The study of distribution of light is absolutely essential to illuminating engineering. Whatever changes in rating may be made, polar curves will still be necessary, and will, we hope, be even more fully utilised in the future.

Nor is there the least likelihood that the useful conception of candlepower will be lost, nor that this term will be banished from our vocabulary.

It is obvious, however, that in referring to the lamps we use every day, in stating in conversation the illuminating value of a source, and in compiling statistics or tables illustrating progress in illuminants, it is impossible to reproduce, either graphically or orally, the polar curve of a lamp every time we have occasion to refer to its illuminating value. For such purposes we must have a number representing, as completely as possible, the potential illuminating power of a source of light. It is now generally accepted that such a number should not represent only the candlepower in a particular direction. The correct procedure is to specify the total light in all directions, recognising that this light can be distributed as we desire by shaping the reflectors, &c., and providing the polar curves relating thereto when required. The general adoption of such a method of rating would mean that in future we should obtain a proper record of improvements in the luminous efficiency of sources, and that whenever any advance is announced we should be able to judge at once whether it was really an improvement in efficiency, and not merely a concentration of light in some particular direction.

The question next arises how this total illuminating power of a lamp is best defined. We have a choice between rating lamps "in mean spherical candlepower" or in the total flux of light in Lumens. The latter quantity is obtained numerically by multiplying the mean spherical candlepower by 12·57 (4π), but is essentially a different unit being the product of the candlepower multiplied by the solid angle over which it operates. We agree that rating in mean spherical candlepower would represent a great advance over present methods, and in the past we have frequently urged the more general use of such values, or at least the provision by manufacturers of a factor enabling the candlepower in the horizontal or maximum direction to be converted into spherical candles. At the same time we have always been impressed by the scientific arguments on behalf of the Lumen, and regarded the adoption of mean spherical candlepower merely as a transition stage in the direction of the Lumen. Now that circumstances seem favourable to the adoption of this unit, there is good ground for the suggestion that we should take the final step.

The scientific arguments in favour of the Lumen may be briefly summarised as follows :—

(1) Mean spherical candlepower is an imaginary quantity. Few, if any, existing sources approach a "point-source" in dimensions, or radiate uniformly in space. But the flux of light in lumens is a real quantity, independent of the area of the source or its distribution.

(2) In every calculation in which mean spherical candlepower is obtained, we must first obtain the total flux of light; the latter, therefore, and not the former, is the fundamental quantity expressing the total illuminating power of a source.

(3) Determination of mean spherical candlepower from polar curves is tedious, and, in the case of sources whose distribution about a vertical axis is not symmetrical (such as lamps with parabolic mirrors, many flames, &c.), very difficult. It is therefore advisable to develop alternative methods of direct measurement, such as the Ulbricht sphere, and these methods essentially measure flux.

(4) Mean spherical candlepower is of no practical utility in calculations. The flux in Lumens is useful, and a knowledge of the flux of light of any beam leads at once to a rapid estimate of the average illumination on any surface on which it impinges. In studying the path of beams of light, and in expressing brightness, the use of Lumens leads to great simplification and avoids the anomaly of two distinct methods as specifying the latter quantity (candlepower per square inch and equivalent foot-candles).

(5) The word Lumen is understood in all the chief countries of Europe and in America. The words used to indicate mean spherical candlepower differ according to the language.

These considerations cover the chief scientific grounds for preferring the Lumen. In addition, the change happens to be convenient from the commercial standpoint. Not only to makers of electric lamps, but also to makers of incandescent gas lamps, the change would be, in the long run, a benefit in enabling us to cut adrift from the uncertainties involved in uni-directional measurement of candlepower. So far from favouring, imposture, rating in Lumens would at once reveal the true values of lamps about which there is at present much dispute. For example, we should appreciate at their true value the relative illuminating powers of half-watt and ordinary metallic filament lamps, and we should also be enabled to see the position of the smaller gas-filled units, for which the candlepower is not stated, and which, while probably marking an advance over the vacuum lamp, are by no means entitled to be described as "half-watts."

As a further precaution against possible misrepresentation, we are strongly of opinion that makers of all types of lamps should make a practice of having standard varieties tested at the National Physical Laboratory and publish the results. These would give, within reasonable limits due to manufacturing discrepancies, an authoritative ruling as to their performance. In this way the change would operate not only as an aid to makers of lamps and lighting appliances, but for the benefit of the general public.

Again, the mere fact that the earliest legislation regarding the measurement of light relates to candlepower is not in itself a good reason for adhering indefinitely to this method. During recent years gas engineers have ceased to attach the importance to measurements of the illuminating power of gas that they once had, and already the value of gas is rated on a calorific basis. There is therefore no valid reason for persisting in rating incandescent gas lamps in candlepower, if Lumen values were found more convenient. We recall that about six years ago Mr. C. O. Bond, in a paper before the American Gas Institute,* entitled "A Survey of Gas Photometry," was already giving results in Lumens per British Thermal Unit per hour.

Lastly, we should like to point out the misconception that the units employed for scientific and technical work must be selected only with a view to continuance of past practice and the convenience of the "man in the street." The selection and definition of such units must be determined by the expert, not by the man who knows nothing about the subject, and naturally cannot be expected to appreciate the importance of a new departure. Having made our decision on scientific grounds, we should naturally do everything possible to make the departure intelligible to the general public, and to introduce it into practice by degrees. The suggestion that the Illuminating Engineering Society should prepare a pamphlet describing the use of the Lumen in simple language, is a good one, and patient educational work will be needed. We may add that the meaning of the term is quite understood by experts, and that the various definitions mentioned in the discussion are mutually consistent. It is only for the sake of scientific precision that further definition is needed, and we hope that a little patience will soon make the term familiar to those interested in its use.

LEON GASTER.

* *Proc. Am. Ges. Institute*, 1911, Part I., p. 537.

TRANSACTIONS

OF

The Illuminating Engineering Society.

(Founded in London, 1909.)

The Illuminating Engineering Society is not, as a body, responsible for the opinions expressed by individual authors or speakers.

THE LUMEN AS A MEASURE OF ILLUMINATING POWER.

(Proceedings at a meeting of the Society held at the House of the Royal Society of Arts, 18, John Street, Adelphi, London, W., at 5 p.m. on Tuesday, January 16th, 1917.

A meeting of the Society took place as stated above on Tuesday, January 16th, 1917, at 5 o'clock, Mr. A. P. TROTTER in the Chair.

The Minutes of the last meeting having been taken as read, the Hon. Secretary read out the names of applicants for membership announced at the last meeting,* and these gentlemen were formally declared members of the Society.

In addition, the names of the following new applicants for membership were announced :—

The Hon. Secretary remarked that the nomination as members of a number of the chief inspectors of the Gas Light & Coke Co., and the South Metropolitan Gas Co., was a gratifying recognition of the importance of the work of the Society. It was to be hoped that other gas companies throughout the Kingdom would follow their lead and nominate a number of their staff as members of the Society.

The Hon. Secretary added that, in accordance with the usual arrangement with the Institutions of Gas and Electrical

Vice-Presidents :—

Broadberry, A. E.	Chief Engineer, Tottenham and District Light, Heat and Power Co., High Street, TOTTENHAM.
Jones, H. E.	Chairman of the National Gas Council, Palace Chambers, WESTMINSTER, S.W.
Watson, D. Milne	Managing Director of the Gas Light and Coke Co., Horseferry Road, WESTMINSTER, S.W.

Ordinary Members :—

Barker, J. W.	Inspector-in-Charge, The Gas Light and Coke Co., 40-42, Barking Road, EAST HAM (1).
Creasey, H. H.	Assistant to the Controller of Gas Sales, The Gas Light and Coke Co., 27, Orpington Road, Winchmore Hill, LONDON, N. (1).

* *Illum. Eng.*, Dec. 1916, p. 365.

Dodimead, H.	Chief Lamp Inspector, The Gas Light and Coke Co., 13, Ranelagh Avenue, Hurlingham, LONDON, S.W. (1).
Eldred, E. W.	Inspector-in-Charge, The Gas Light and Coke Co., 19, Lancaster Road, STROUD GREEN, N. (1).
Field, G. H.	Inspector-in-Charge, The Gas Light and Coke Co., 81, Holland Road, WILLESDEN, N.W. (1).
Higgs, S. D.	Inspector-in-Charge, The Gas Light and Coke Co., 178, Elsenham Street, SOUTHFIELDS (1).
Holgate, R. D.	High Pressure Gas Lighting Dept., South Metropolitan Gas Co., 71, Calton Road, DULWICH, S.E. (1).
Hollest, E. H.	Inspector-in-Charge, The Gas Light and Coke Co., 13, Cleveland Parade, George Lane, WOODFORD, N.E. (1).
How, S. J.	Technical Officer, Special Lighting Installation Section of the Gas Light and Coke Co., 8, Leppoc Road, CLAPHAM PARK, S.W. (1).
Jeffrey, W. H.	Superintendent, Mantle Maintenance of the Gas Light and Coke Co., ILFORD; 16, Norwich Road, Thornton Heath, SURREY (1).
Kevan, E.	Inspector-in-Charge, The Gas Light and Coke Co., 32, Selwyn Avenue, HARLESDEN, N.W. (1).
Lloyd, G. H.	Inspector-in-Charge, The Gas Light and Coke Co., 19, Alcester Crescent, UPPER CLAPTON, N.E. (1).
Mead, H. S.	Inspector-in-Charge, The Gas Lighting and Coke Co., 44, Alexandra Road, SOUTH WOODFORD (1).
Merry, E. G.	Inspector-in-Charge, The Gas Light and Coke Co., 45, Connaught Road, HARLESDEN, N.W. (1).
Palmer, A. W.	Inspector-in-Charge, The Gas Light and Coke Co., Ripple Road, BARKING (1).
Phillips, J. W.	Inspector-in-Charge, The Gas Light and Coke Co., 25, Manor Park Road, HARLESDEN, N.W. (1).
Pilbrow, E.	Inspector-in-Charge, The Gas Light and Coke Co., 1, Carlyle Square, CHELSEA, S.W. (1).
Roberts, S. J.	Inspector-in-Charge, The Gas Light and Coke Co., 9, The Broadway, WOODFORD GREEN (1).
Strang, H. K. W.	Inspector-in-Charge, The Gas Light and Coke Co., 31, Kinfauns Road, Goodmayes, SUSSEX (1).
Sutton, E. L.	Inspector-in-Charge, The Gas Lighting and Coke Co., 63A, Golders Green Road, HENDON, N.W. (1).
Walters, B. H.	Inspector-in-Charge, The Gas Light and Coke Co., 82, Elsenham Street, SOUTHFIELDS (1).
Watling, S.	Gas Inspector of the Gas Light and Coke Co., 5, Glenbrook Road, WEST HAMPSTEAD (1).
Webber, A. H.	Inspector-in-Charge, The Gas Light and Coke Co., "The Nook," Staines Road, SUNBURY (1).

Engineers, Mr. A. E. Broadberry, the President of the Institution of Gas Engineers for the current year, had been created a Vice-President and member of Council of the Society.

The Society had also been honoured by acceptance to act as Vice-Presidents on the part of Mr. HARRY E. JONES, the Chairman of the newly-formed National Gas Council, and Mr. D. MILNE WATSON, the Managing Director of the Gas Light and Coke Co., who would take the place left vacant by the death of the late Sir Corbet Woodall.

The Chairman then called upon Professor J. T. MORRIS to open the discussion on **The Lumen as a Measure of Illuminating Power,** and Mr. F. W. WILLCOX subsequently presented a contribution to the discussion in which this subject was fully treated by the aid of appropriate curves and diagrams (see pp. 10-25).

In the subsequent discussion Mr. S. H. CALLOW, Mr. A. BLOK, Mr. J. G. CLARK, Mr. L. RABONIVITCH, Mr. G. CAMPBELL, Mr. E. STROUD, Mr. R. A. IVES, Mr. A. WISE, Mr. C. H. PITMAN, Mr. J. S. DOW, and Mr. L. GASTER took part.

The CHAIRMAN, in winding up the discussion, alluded to the importance of the proposal that lamps should be rated in terms of the total flux of light and emphasised the need for a thoroughly scientific and precise definition of the Lumen. Professor MORRIS and Mr. WILLCOX briefly replied to some of the points raised.

The Chairman announced that the next meeting would take place on Tuesday, February 20th, when a paper would be read by Dr. JAMES KERR (*Public Health Dept., London County Council*), on **The Effect on the Eye of varying degrees of Brightness and Contrast.**

THE LUMEN AS A MEASURE OF ILLUMINATING POWER.

BY J. T. MORRIS.

(Professor of Electrical Engineering at East London College).

(Introduction to the discussion of the Illuminating Engineering Society held at the House of the Royal Society of Arts, 18, John Street, Adelphi, London, W., at 5 p.m., on Tuesday, January 16th, 1917.)

AT a discussion of the Society held in March, 1915, the rating of illuminants in terms of consumption of gas or electricity and illuminatng value was discussed.

It was then pointed out that the distribution of light from modern illuminants differs so greatly, and can be modified so readily by the use of appropriate globes and reflectors, that no method of evaluation based on the light emitted in any one direction is satisfactory. It is now generally agreed that illuminants should be rated in terms of the total amount of light yielded in all directions, although information regarding the distribution of light (polar curves, &c.) is necessary for certain purposes.

What exactly is meant by the statement that the candlepower of an incandescent electric lamp is, say 50? The statement implies that if we divest the lamp of its fittings, and then measure the candlepower in a horizontal direction, the illumination derived will be 50 times that obtained from a standard candle placed at the same distance. But such a value bears no relation to the performance of the lamp in practice. Nowadays it is essential to use most lamps with an appropriate globe or reflector, and one could hardly mention a lamp without thinking of it as a complete unit with its proper shade or reflector around it. Many such complete units, for example those specially designed for street lighting, give practically no candlepower in the horizontal direction.

It is clearly necessary to take into account the candlepower from the lamp in other directions as well as that in the horizontal direction; for (assuming that

the distribution of light is symmetrical about a vertical axis) the candlepower at all angles can be represented by the well-known polar curve of light distribution. Such curves are essential to the expert in judging the suitability of lighting units for various purposes, but the information contained in such curves could not readily be summarised in a single figure for rating purposes.

Further, there are other sources, such as the half watt lamp, the candlepower of which in a horizontal direction is difficult to determine, a small change in angle making a considerable difference in candlepower. Without a clear agreement as to the conditions under which candlepower is to be measured, it is very difficult, when rating their efficiency, to compare such lamps with one another or with ordinary tungsten lamps.

Therefore the only proper basis of comparison of such lamps must be in terms of the total amount of light emitted in *all* directions.

The desirability of rating illuminants in terms of mean spherical candlepower has been often urged. The adoption of this would lead to the presentation of lower numerical values than those previously put forward, which from a commercial standpoint is objectionable. In addition, the mean spherical candlepower is only an imaginary quantity and somewhat difficult of conception, since in practice we do not meet with any source which gives exactly the same candlepower in all directions. The nearest approximation to such a source is the "Pointolite" lamp invented by Lieut. Mullard of the Edison and Swan Electric Co., which was shown before the Society in the Autumn of 1915. In the case of the great majority of lamps, and especially lighting units comprising a lamp within a globe or reflector, the light emitted in different directions varies enormously. In order to conceive of the mean spherical candlepower it is therefore necessary to imagine that the source gives out the same total amount of light but redistributed so as to be equal in all directions, as is practically the case in the white hot ball of tungsten in the Pointolite Lamp, as already stated.

It is clear that if mean spherical candlepower were to be generally adopted for the rating of lamps the candlepowers assigned to them would be, in almost all cases, considerably lower than that credited to them by present methods. In practice this might not be convenient. If a consumer found that he was being offered a lamp of the same consumption as before but with say 100 instead of 120 c.p. he would be apt to jump to the conclusion that it was a poorer article and it would then be necessary to try to explain to him the difference between mean spherical candlepower and mean horizontal. This might seem a small point but it is one that the Society would have to consider were they to recommend a change in rating.

Recently, however, the suggestion has been brought forward that lamps should be rated in terms of the total flux of light, the unit of which is the Lumen. This term was originally proposed by Professor Blondel, of Paris, at the International Electrical Congress at Geneva in 1896. While the exact definition to be given to this term may be a subject for the consideration of the Society, it is perhaps best explained as the flux of light received by a surface one square foot in area, and having an illumination over its area of one foot-candle. In view of the fact that during recent years the foot-candle has become such a familiar unit in this country, this is perhaps the easiest method of approaching the conception of the Lumen. The above definition is also equivalent to stating that the Lumen is the flux of light emitted by a source of unit candlepower in unit solid angle. The solid angle subtended at its centre by a spherical surface is 4π, and the flux in Lumens from any source is therefore obtained by multiplying the mean spherical candlepower by this figure.

On the Lumen rating, therefore, a 40 c.p. lamp would be sold as a 350 or 400 Lumen lamp in future. This is a much larger figure, and some people consider that in illuminating engineering calculations this is an advantage. In addition, by breaking new ground and adopting a new system of rating, the difficulty of the apparent reduction in candlepower of lamps arising through rating in mean spherical candlepower would be avoided.

In the Report of the Committee of the American Illuminating Engineering Society on Nomenclature and Standards

presented at the Convention last September, it is definitely specified that illuminants should be rated in terms of Lumens in the future and it is understood that this decision will be adopted and put into practice by the lamp makers in the United States. It is believed that in Germany the whole question of the rating of lamps is also being discussed, but the final consideration of the matter by the Illuminating Engineering Society Committee in that country appears to have been suspended owing to the war.

In this country, also, it seems that the makers of electric lamps contemplate adopting the Lumen, though it may be necessary also to state candle-power values and to show their relation to Lumen values during the transition period. Obviously the change must be accompanied by efforts to make the new method of rating widely known and understood. Again, once the lamp makers have adopted the necessary photometric apparatus the ease of measurement and certainty of the result will recommend methods based on the measurement of total flux of light.

It will be observed that, apart from the loss of light involved by the use of a globe or reflector with a lamp, the output of the combined unit in Lumens should not be affected by any measures that are taken to alter the distribution of light. If the Lumens in each zone from such a unit are tabulated the summation of these values gives at once the total flux of light, and by comparing this with the output in Lumens of the lamp used, the efficiency of the globe or reflector can be readily ascertained. This is an interesting point because the method would reveal many cases in practice where the flux of light available from the lamps used has not been efficiently utilised and would suggest opportunities for improvements in the existing methods of distributing light.

It is also convenient to work with Lumens in the usual formulae for determining the average illumination in a room resulting from a given arrangement of lamps, and particularly when the approximate average illumination over an area needs to be quickly determined. It also facilitates calculation of the illumination derived from extensive illuminated surfaces, such as occur in the case of indirect lighting. Again we find ourselves almost compelled to utilise the conception of flux of light when dealing with concentrated beams such as occur in the searchlight and the optical lantern. In dealing with the illuminating value of beams differing in dispersion, rating of the unit in terms of Lumens is certainly worthy of careful consideration.

The time is therefore ripe for the discussion of this subject by the Illuminating Engineering Society, and it is hoped that this meeting will be useful in eliciting the views of those concerned both with the rating of lamps and their use in practice.

JUVENILE EMPLOYMENT.

Attention has recently been drawn to the admirable researches carried out under the supervision of the Committee on the Health of Munition Workers on the relations between hours of work and fatigue.

In a recently issued Bulletin (No. 13) the conditions of juvenile labour in factories is discussed. It is pointed out that many factors that have a depressing effect on workers generally, especially overtime, have a specially bad effect on children. Expressions of opinion of factory inspectors are quoted to the effect that in many workshops children are being seriously overworked. Continued long hours give rise to a condition of general lassitude, dullness, and weariness that must have a prejudicial effect alike on the work and the health of the children. It is strongly advised that in no case should boys under 16 work for more than 60 hours a week. Eight hours of sleep are the minimum.

Equally important is the general care of children to whom the general supervision and guidance of older people is often essential. Facilities for recreation can do much to prevent staleness and fatigue. An interesting account is given of the work of Boy Visitors, who appear to be doing a most valuable work in supervising the well-being of juvenile workers and removing conditions that may lead to permanent deterioration in physique.

THE LUMEN AS A MEASURE OF ILLUMINATING POWER.

By F. W. Willcox.

(Contribution to the Discussion of the Illuminating Engineering Society held at the House of the Royal Society of Arts, 18, John Street, Adelphi, W., at 5 p.m. on Tuesday, January 16th, 1917.

This is the third time within the writer's knowledge that the subject of the Lumen has been discussed before this Society. The first occasion was the very able paper by Mr. A. P. Trotter on "Nomenclature and Definition of Photometric Magnitudes and Units" before the Illuminating Engineering Society's meeting, May 31st, 1914.

Again, at the March 16th, 1915, meeting of this Society, the writer presented a paper on the "Practical Rating of Incandescent Lamps," the latter part of which was devoted to a discusion of the Lumen as the desirable unit for expressing luminous values.

Mr. Trotter in his paper presented a most able argument in favour of the retention of candlepower as against the adoption of a new unit, but the writer thinks it is clearly shown in the discussion contributed by Mr. C. C. Paterson and Prof. Blondel, that the trend of scientific work and definitions was at variance with the ideas and system advanced by Mr. Trotter, and that evolution of practical experience unavoidably leads to a flux conception in lighting problems.

Since that time, developments in illuminating work, particularly in electric lamps, with the increasing varieties of filament shapes, have emphasized more than ever the need of some more definite unit than candlepower for expressing luminous values. As Prof. Blondel stated, photometric units should be—

1st, Scientific—that is to say, in direct and intimate relation with other branches of physics and carried to the same degree of scientific precision.

2nd, International—that is to say, containing terms capable of being adopted for all countries.

He pointed out that the word "*candle-power*" is not possible to adopt internationally, because while such a term is rendered venerable by its years of usage in England, it is completely unknown in other than Anglo-Saxon countries.

Prof. Blondel then states "the photometric system should be framed to meet the requirements of science, and not to comply with the old-fashioned practices dating from the early days of public lighting, nor to meet the views of those who, as Mr. Trotter says, 'know little or nothing about angles and flux.' On the contrary, the system should be *in advance* of its time. It should provide engineers with scientific ideas of illumination and conceptions in harmony with the progress of other branches of physics. It is for these reasons that it is necessary to define luminous flux (a special form of energy) before proceeding to define the source of light. The conception of a flux is so convenient in practical lighting problems, both as regards interior and public lighting, that people have come to make constant use of it, and in fact can hardly avoid doing so. And how is it possible to define illumination in a scientific manner without recourse to this quantity."

Supplementing these points, Mr. C. C. Paterson, of the National Physical Laboratory, said that the conceptions of light as a flux is a very natural and common one, and the expressions frequently used, such as a lamp "shedding" light, and "floods of light" indicate that the common every-day conception of light is that of a flux and not that of illumination.

Mr. Paterson further stated: "I really do not think it is possible to get rid of flux as the primary idea in light, for the reason that if we look at all other branches of physics where radiation or its equivalent is concerned, there is none in

which the idea of flux is not the fundamental one." He instances the cases of sound, heat and magnetism as subject to this condition. He then says: "This being the case, I think with light we ought to keep our definitions on all fours with our definitions and conceptions in other branches of science. Radiated energy is always thought of, not as the source which is radiating it, but as the 'something' which is passing through the ether towards us. Therefore I venture to suggest that if we adopt Mr. Trotter's suggestion we shall be introducing an entirely new system into scientific definitions, and we ought to have some very good reason indeed before deciding to do so."

These remarks deal with the important theoretical points in the discussion of May, 1914. In the paper the writer presented at the April, 1915, meeting, he endeavoured to give some practical reasons in support of the Lumen as bearing on the question of Electric Incandescent Lamps.

It is proposed in this paper to summarise the situation to date, which necessarily, of course, includes a repetition of some of the points already presented, in order to present a full case for Lumen and show its practical value and application in lighting and illumination problems. In order to do this, it would be well for us to start with the deficiencies of candlepower as a unit, which deficiencies are becoming increasingly emphasized from year to year, and have rendered it necessary seriously to consider a more suitable unit for definitely expressing luminous values. Candlepower will be retained as the unit of luminous intensity, but just as in the case of a pump, the pressure which the pump exerts gives no proper indication of its capacity, so in the case of illuminants the candlepower gives no complete indication of the actual quantity of light given by the illuminant.

Defects of Candlepower Rating.

The fundamental requirement is a definite unit which will always clearly and invariably express one thing. This condition the Lumen complies with and the candlepower unit does not. We well know, for example, the numerous varieties of candlepower, such as the mean horizontal, mean spherical, the upper mean hemispherical, and the lower mean hemispherical, the maximum candlepower values in different directions, and the "apparent" candlepower values obtained when we put a lamp in a reflector and re-distribute the light. Such complications do not arise with the Lumen. When employed either as a measure of luminous value or to express the efficiency of the illuminant, its terms are precise. For example, when we express the efficiency of an electric lamp in the usual term "watts per candle," a query arises as to what variety of candle is meant—whether the mean spherical or the mean horizontal or the tip end value, etc.—whereas "watts per lumen" or "lumens per watt" is wholly definite.

Again, the unit of luminous values should not permit of manipulation by the alteraton of its apparent value through change of the shape of the luminous body (the lamp filament) or through the use of any external accessories, such as reflectors, etc. Experience has shown that alteration of values by this means has been the chief defect of candlepower as a unit. Numerous examples may be given, as it is common knowledge how the filament of an electric lamp can be reshaped and concentrated so as to give its maximum value in any given direction, and by simply frosting or silvering the upper part of the glass bulb, a lamp may be made to give apparently very much increased candlepower value for the same energy from the same length and section of filament.

Again, the variations in candlepower values obtainable in different directions with different kinds and shapes of reflectors is well known to all. The same amount of light flux (Lumens) is made to give—now 50, now 100, now 500 or more candlepower value.

It is not necessary to labour these points, and I will simply refer my audience to the illustrations accompanying the paper.

Fig. 1 shows the various forms of electric lamp filaments and indicates the exceeding difficulty of trying to assign candlepower values to many of these

shapes. This is apparent when we consider the light distributions as shown in Figs. 2, 3, 4 and 5. When we consider such cases, the use of the Lumen strongly recommends itself, for the simple reason that the Lumen cannot be manipulated. The luminous output of a lamp as expressed in Lumens remains the same, whatever the shape of the filament, and no matter what variations of external arrangements or what accessories (reflectors, etc.) are employed with the lamp (always of course allowing for any absorption losses there may be in the accessories).

A good example of the value of a definite unit such as the Lumen for the purpose of accurately recording steps in progress in lighting is afforded by the curves shown in Fig. 6.

In this figure the advances in the efficiency of conversion of energy into light in electric incandescent lamps is traced, from the earliest developments up to the present date. Here we see how a unidirectional method of expressing candlepower fails to give a proper measure of the illuminating power of the half watt lamp.

Similar results would doubtless be obtained if the changes in efficiency of other illuminants were plotted in a diagram of this kind. For in all such cases advances in efficiency are commonly accompanied by changes in the distribution of light. The curve giving the values in Lumens per watt, however, gives a true record of the advance secured.

A further serious defect of candlepower is that the value materially alters (as in the case of light distribution curves), according to the direction in

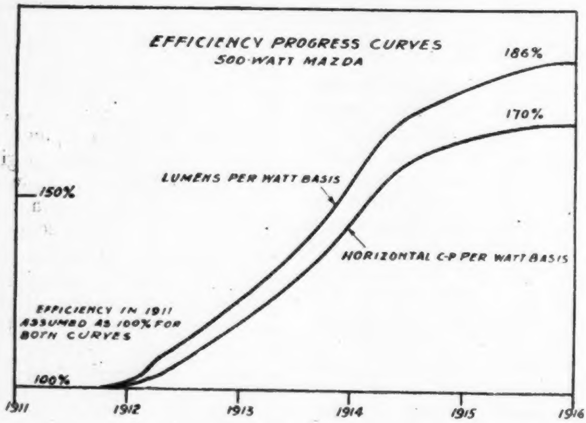

FIG. 6.—Advance in electric incandescent lamp efficiency.

The above curves show the advance in the efficiency of electric lamps over a number of years. The lower curve expresses the efficiency in "*Horizontal Candlepower per Watt*"; the upper curve the efficiency in "*Lumens per Watt.*" It will be observed that the two curves are parallel up to a point, until the Gas-filled ("Half Watt") Type Lamp enters in, and from here onwards the "Lumens per Watt" curve rises more rapidly than the other curve. This is explained by the fact that the new Gas-filled Type Lamps have a different spherical reduction factor from that of the previous Vacuum Type Lamps. The improvement in efficiency given by the Gas Filled Type Lamps is thus not fully expressed by the curve expressing "Horizontal Candlepower per Watt." With "Lumens per Watt," as expressed by the upper curve, we have the full case accurately represented for the new type and for all types of lamps, thus giving a true and full record of lamp development.

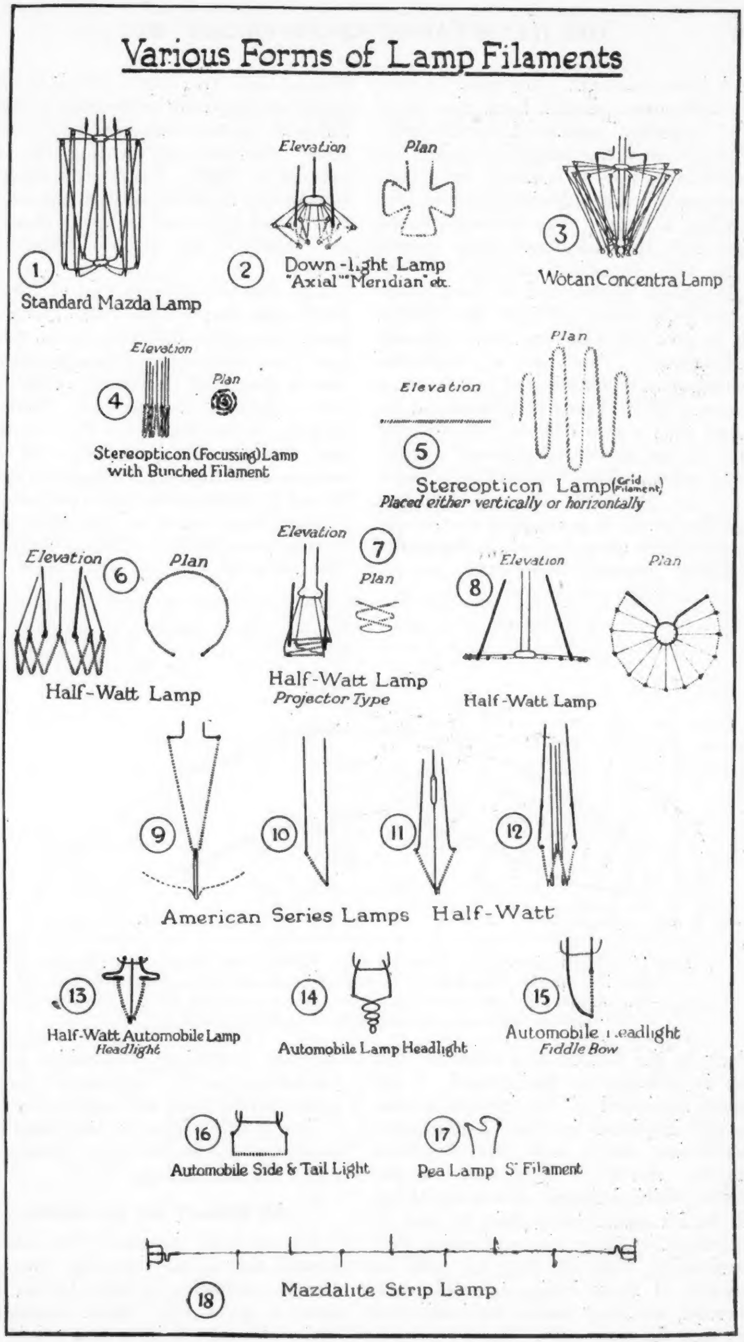

FIG. 1.—Various Forms of Electric Lamp Filaments, showing the impracticability of rating in candlepower values.

which it is measured. Practically a unit of candlepower should have the same value whether measured horizontally, vertically, or at any angle. Actually we know it does not, as is shown by a consideration of the spherical surface surrounding a lamp. The average person quite fails to understand why merely taking the numerical average of the candlepowers represented at each point on the polar curve of light distribution fails to give the value in mean spherical candlepower. This is a somewhat mysterious and complicated problem to a layman. Even those who understand the subject fully are in difficulty to properly judge of the merits of different candlepower curves without employing a planimeter or Rousseau diagram. Such a condition tends to misleading results and frequent misrepresentations in support of unfulfilled claims. Whenever anyone is hopeless to ever expect people to understand the apparent inconsistency of these different curves containing very unequal areas and yet representing the same volume of light. These difficulties are continually emphasized with the elaboration of reflectors and forms of glassware, as employed in modern illumination work.

The case is no longer that of the early days—the simple light value given by a lamp in a given direction. The modern case must provide for expressing luminous values given by lamps in combination with reflectors or glassware, distributed directly or indirectly via the ceiling, or part directly and part indirectly as in semi-indirect lighting. Diagrams in Figs. 10 and 11 illustrate this point and show two characteristic cases of the light distribution from modern lighting equipment. The idea of flux of light suits these

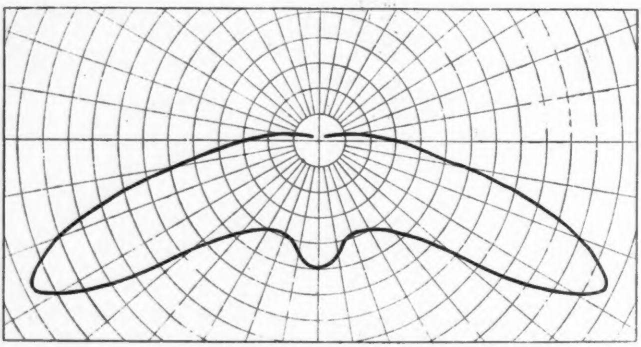

FIG. 11.—Light distribution from "Strela" Fitting, with Holophane Refractor, showing special character of light distribution desirable for street lighting—a contrast with the distribution curve shown in Fig. 10, and illustrating the extreme variations to be dealt with in lighting problems.

objects to the Lumen as a scientific unit that is difficult to understand, I am always reminded of the exceeding complexity involved in the candlepower distribution curves and the Rousseau diagram. Surely a unit such as the Lumen, which definitely means one thing, will be far easier to explain to and be understood by those who are dealing with illumination, than candlepower with its varieties of mean horizontal and mean spherical, etc., and such complications as Rousseau diagrams, etc.

Diagrams in Figs. 7, 8, and 9 clearly illustrate the difficulties just stated. It complex conditions admirably, and the Lumen correctly expresses luminous values for all cases and conditions

The general idea of the Lumen and candlepower can be quite clearly illustrated by an analogy.

An Analogy for the Lumen.

Let us take the case of a lake, and assume that it had been the practice to rate the capacity of lakes by the depth along a given line, drawn through the centre of a lake at its widest point. This average depth would correspond with the mean horizontal candlepower of a lamp.

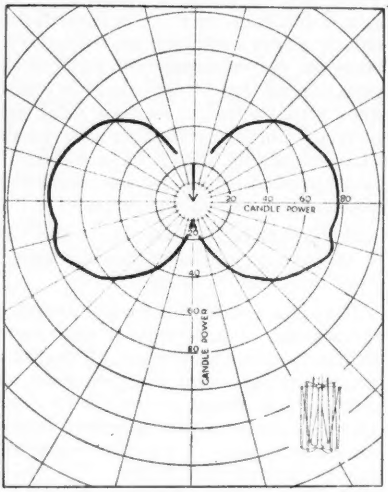

FIG. 2.—Light distribution from 100 watt Standard Metal Filament Lamps. (Filament No. 1 in Fig. 1.)

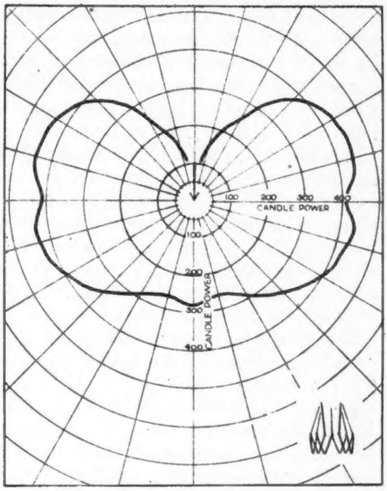

FIG. 4.—Light distribution from 300 watt Half-watt Type Lamp. (Filament No. 6 in Fig. 1.)

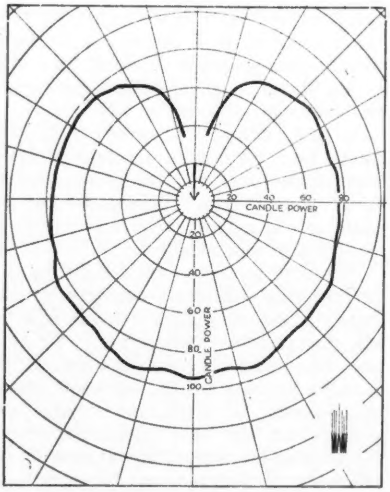

FIG. 3.—Light distribution from 100 watt Focusing Lamps. (Filament No. 4 in Fig. 1.)

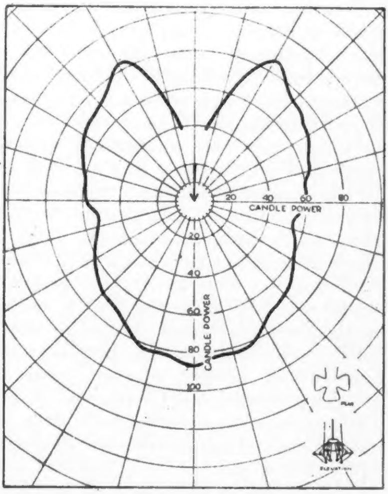

FIG. 5.—Light distribution from 100 watt Spiralised Filament Lamps. (Filament No. 2. in Fig. 1.)

This form of measnre would do fairly well so long as lakes have a general common contour at the bottom and similar surface areas. It would be manifestly a very incorrect measure for lakes of different shapes and sizes, *e.g.*, long lakes like a river, as compared with round lakes or lakes of wholly irregular shapes. It would also be evident that this method of measurement could be abused by any owner of a lake digging out a section of it along the centre line to greater depth so as to claim that his lake, by reason of its greater average depth, had a greater capacity than some other lake. If the average depth were taken covering all points in the lake, we would have a more definite measure of the lake's capacity. This would correspond to the mean spherical candlepower basis for a lamp, Even this measure, however, would not be much less satisfactory as a basis for clearly expressing the volume of water in lakes of widely varying shapes. A more definite measure specifying the volume of water, such as a statement of the number of gallons, would be desirable. This measure would be analogous to the Lumen.

Another analogy can be drawn from casks or barrels. Supposing it had been the practice to rate the capacity of barrels by the diameter of the barrel at the centre or bung hole section. This would be a fairly satisfactory measure, so long as the barrels were of the same general shape and length, but it would manifestly be wholly an unsatisfactory measure with carks of different lengths and varying shapes. A cask, for example, built in the form of a long tube (such as the tanks employed to ship gas under pressure) would have to have the length as well as the diameter stated. Casks or barrels built in the shape of the English milk-cans would present another variation requiring special treatment, and so on. Ultimately, some other measure than the convenient and simple diameter dimension of the cask would have to be adopted, such as the gallons or cubic feet of the liquid the cask would hold, or, to be more exact, the gallons of some given liquid, *e.g.*, water at a specific density. In this analogy, the diameter of the cask would correspond to candlepower, and the gallons to the Lumen.

The Lumen Defined and Explained.

The Lumen is strictly defined as the unit of luminous flux. Luminous flux is radiant power evaluated according to its visibility, *i.e.*, its capacity to produce the sensation of light. This sounds somewhat formidable, but so does a full and correct definition of most terms or words. I daresay the full definition of a kilogram would dismay numbers who employ it constantly in buying and selling.

Briefly stated, the Lumen is the unit of the quantity of light flowing from a lamp or luminous source.

The value established for the Lumen is the amount of light from a unit source falling upon a unit surface, all points of which are at a unit distance from the source. Let us be more specific, and assume a source of one spherical English candle, and place this at the centre of a sphere of one foot radius. It follows that the Lumen is the amount of light which is falling upon one square foot of surface of this sphere. The total area of a sphere with one foot radius is 4π or 12·57 square feet. As each square foot represents a value of one Lumen there will therefore be 12·57 Lumens on the total sphere. It follows from this that the lighting value in Lumens of any lamp or luminous source is obtained by multiplying the mean spherical candlepower of the source by this figure, 12.57.

It follows from the above definition that a Lumen will give an intensity of one foot candle over an area of one square foot. The average illumination at all points of our unit sphere mentioned above will be one foot candle.

We thus have the total light output of the lamp definitely measured by the Lumens, instead of light intensity in some one direction by candlepower. We have the illumination values measured by Lumens per square foot. As each Lumen corresponds to one foot candle per square foot, the term " foot candles per square foot per watt " (the expression for efficiency of illumination) becomes more simply " Lumens per watt." We also have the efficiency of the lamp clearly and fully measured by Lumens per watt, instead of watts per candle. The brightness of a surface, either " self-luminious " and radiating light, or made luminous

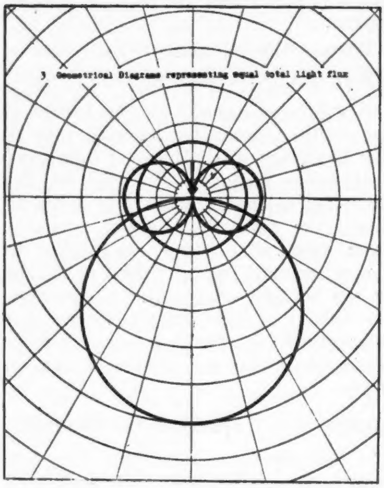

FIG. 7.—Ideal Curves, showing same total light flux. Each curve expresses equal illuminating value (the same total lumens) but apparently very different candlepower values.

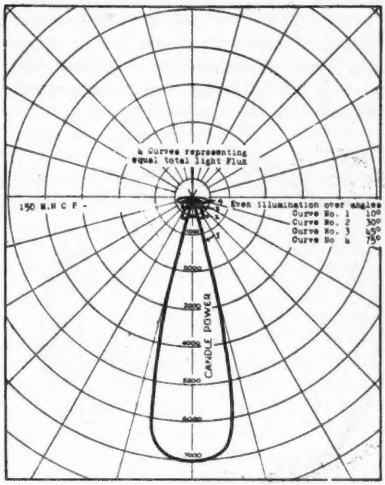

FIG. 9.—Diagram showing how, in an extreme case, the same total light flux may be distributed so as to show very misleading apparent values of candlepower.

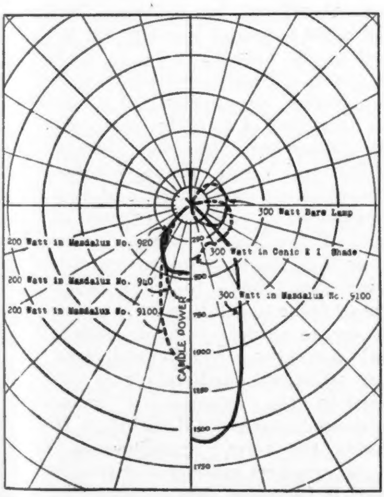

FIG. 8. Apparent variation in candlepower from a 300 watt Lamp, through use of various reflectors.

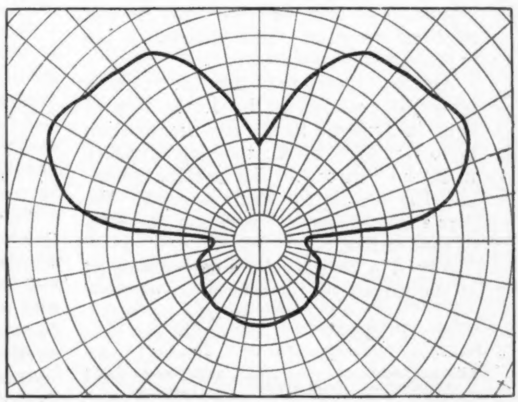

FIG. 10.—Light distribution from Veluria Hemisphere, showing the complex character of light distribution with modern lighting equipment.

by reflected light, may be preferably expressed in terms of Lumens per sq. ft. or per sq. cm. instead of candles per square foot or per square inch or in "equivalent foot-candles." Thus the Lumen is an all-round term of general application in lighting work.

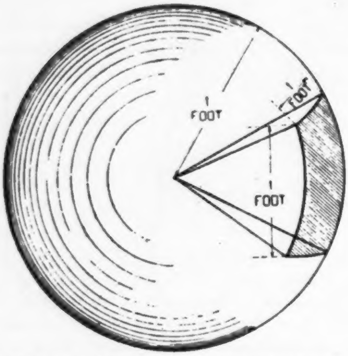

FIG. 12.—Graphical Representation of the Lumen.

In Fig. 12 is given a graphical representation of the Lumen shown by means of the unit sphere.

It may be a help towards a clear conception of the meaning of candlepower, illumination and flux of light if the relations between these quantities are expressed mathematically.

Assume therefore that the candlepower is represented by I, the flux of light in Lumens by F, the illumination in foot-candles by E, that the distance from the source to the surface illuminated is R, and the angle at which the rays strike the surface is θ, and the area of this surface S.

Now if A be the solid angle subtended at the surface by the source, we have:—

$$F = I \times A = \frac{I \times S \cos\theta}{R^2}$$

$$\left[\text{Flux of Light} = \text{Candlepower} \times \text{Solid Angle} = \frac{\text{Candlepower} \times \text{Area}}{(\text{Distance})^2}\right]$$

$$E = F/S \cos\theta = \frac{I}{R^2}$$

$$\left[\text{Illumination} = \frac{\text{Flux}}{\text{Area}} = \frac{\text{Candlepower}}{(\text{Distance})^2}\right]$$

If we desire to obtain the *total flux* emitted by a source we must multiply the mean spherical candlepower by the entire solid angle over which it operates, which is, in circular measure, $4\pi = 12{\cdot}57$ approx.

Whence the relation:—

Flux of Light = Mean Sph. C.P. $\times 4\pi$.

It will be observed that the Lumen is essentially a quantity denoting rate of flow of energy in the form of light, and is therefore analogous to, and of the same dimensions as watts. In order to obtain the total light-output during a given interval of time, analogous to energy, we must multiply the flux of light by the period during which it operates. The output of light from a source in a given time is therefore conveniently expressed in lumen-seconds or lumen-hours.

Lumen *versus* Spherical Candlepower.

In the previous discussions on this subject, the deficiencies of candlepower were admitted by almost every one discussing the matter. Many, however, seem to have been of the opinion that the adoption of "mean spherical candlepower" would solve the difficulties, and they were therefore not favourable to the adoption of the Lumen. It becomes desirable, therefore, to consider the merits of mean spherical candlepower as compared to the Lumen.

Mean spherical candlepower as a unit is best described as a mouthful. The term is a compound of a number of words, generally expressed by the letters "M.S.C.P.," which will always be more or less cryptic to most people, and can hardly be called a practical expression for a unit. If the unit of luminous value was to be the mean spherical candlepower, we would have to adopt some new term or name to call it by. It is too cumbersome an expression as it stands, and would not serve. Another objection to mean spherical candlepower is its similarity to the expression "mean horizontal candlepower" (M.H.C.P.). It perpetuates the term "candlepower" with the inheritances associated with this term, and is therefore sure to result in confusion, not only in the minds of laymen, but of engineers as well.

It is certainly much better, in adopting the flux idea for expressing luminous output, to entirely drop the term "candle-

power " in any expression for this unit, and substitute an entirely new term, such as the Lumen. In this way, we cut loose from all the previous deficiencies and misconceptions associated with the term " candlepower " as set forth herein. It may be somewhat difficult to adapt every one's mind to the use of the new term " Lumen," but such an obstacle would be far easier to overcome, in the writer's opinion, than it will be to instil in everybody's mind an intelligent understanding and use of the terms " mean horizontal," " mean spherical," " tip end candlepower," etc.

The conception of mean spherical candlepower does not lend itself readily to express the volume of light in any given zone or section of space surrounding a luminous source. It is difficult, for example, to conceive expressing the amount of light in a 10° zone (beneath a lamp in a reflector as shown in Fig. 13), as so many " mean spherical candlepowers." The conception is perfectly clear, however, when we express the volume of light in these zones in Lumens. The term candlepower has already been allocated to the specification of the intensity of light in different directions. It is therefore far better not to repeat this term (in the form of mean spherical candlepower) to indicate the summation of the light yielded in a number of directions, but to indicate this quantity, the flux of light, by an entirely new unit, the Lumen. The practical reasons mentioned above furnish strong grounds, in the writer's opinion, for the adoption of an entirely new term or unit instead of the cumbersome term and conception of " mean spherical candlepower."

Again, mean spherical candlepower does not lend itself to expression illumination values as the Lumen does. We have noted above that the Lumens per square foot can be used as a unit of illumination intensities as a substitutes for the expression " foot candles," and that " Lumens per watt " is a simple expression for the efficiency of illumination, as a substitute for the present term " foot candles per square foot per watt."

If the majority of engineers are clearly in agreement, as previous discussions show, as to the desirability of some more comprehensive unit, such as the " mean spherical candlepower," surely it is a small matter as to whether we go a step further, and have an entirely new unit, but with a more simple name ; one freed from any limiting preconceptions and conditions associated with candlepower ; one which is scientifically correct and properly co-ordinated in a complete system of lighting units, and one therefore more fully and better qualified to express clearly and definitely the conception of light as a flux—the fundamental idea where a radiation such as light is concerned.

I think the conclusions are unavoidably in favour of the Lumen, and that inevitably the merits of the Lumen will ultimately force its adoption, in spite of individual opinions to the contrary. It therefore seems desirable that the way should be opened for the free use of this new unit, and its adoption promoted in every way by the full co-operation of manufacturers of lighting appliances and illuminating engineers generally.

I am happy to say that this programme has already been put into effect by a number of the leading electric lamp manufacturers in Great Britain, as well as by the Holophane Company, who are adopting the plan of expressing their luminous ratings in Lumens.

The hesitation or fear that many express about adopting or popularising a new term seem more or less exaggerated to the writer. No doubt these fears arise on every similar occasion, but the industry and the public having lived through and become accustomed to the electrical terms of kilowatts, amperes, and volts, not to mention others in connection with other industries, and this same public will find no serious difficulty in sooner or later thinking and expressing luminous values in Lumens.

I recognise that it is desirable to define the Lumen with the greatest possible precision from a scientific standpoint, and also to take measures to render the term intelligible to the general public. But, from a practical standpoint, the public are less concerned with exact scientific definition of a quantity than with the visualising, in practice, of what it represents. For example it is much more important that a man who is adopting the metric system should appreciate that

a kilogram is approximately equal to 2·2 lbs., and should thus form a clear idea of the weight of a kilogram, than that he should be informed as to the exact way in which this unit is defined and preserved.

For a time, as in the case of all similar transitions, people's minds will think in candlepowers as well as Lumens, but sooner or later Lumens will be used more or less entirely as the unit, in the same way that the kilogramme has displaced the former units of weight used in countries where the metric system has been adopted.

In the end, such a change will have many benefits in simplifying the whole subject of illumination. We have at the present time, in the measurement of light and illumination, three distinct units — candlepower, mean spherical candlepower, and foot candles. The Lumen gives us one unit and term to serve generally in place of all these units.* The Lumen expresses the luminous output for all conditions in place of candlepower, mean spherical candlepower, etc. The Lumens per square foot expresses the intensity of illumination and brightness in place of foot-candles, and the Lumens per watt with electricity, or per cubic foot for gas expresses the efficiency of a luminous source, taking all conditions and variations into consideration affecting the shape of the burner or the equipment of the lamp.

Practical Employment of the Lumen.

The adoption of the term "Lumen" and familiarity therewith makes it easy to lay out lighting systems. In employing Lumens in practical illuminating problems, engineers have recourse to what is known as the utilisation efficiency factor, which expresses the efficiency of utilisation of the light. This is nothing more than the percentage of the total amount of Lumens given by a luminous source which is made available upon the working plane or illumination area considered. These utilisation efficiencies vary from 60 per cent. to 70 per cent. down to as low as 15 per cent. to 20 per cent. They depend essentially on the colour and character of walls and ceiling, and amount of light reflected therefrom. They are determined for the different characters of interiors and for different systems of lighting, and when determined are tabulated in convenient table form for use.

In lighting a room, the area of the room in square feet is multiplied by the intensity desired in foot-candles. This at once gives the net Lumens required. To find the total Lumens required from the lamps, we divide the net Lumens by the utilisation efficiency or factor decimally expressed. We then have the total Lumens which the lamps must give, and by reference to a table of Lumen values for the various sizes of lamps, we can select the most suitable size to accord with the desired number of points to be fixed, or we modify the number of points to accord with the Lumen value of some desired size of lamp. The simple equation for such work is :—

$$\frac{\text{Floor area in sq. feet} \times \text{Intensity in foot-candles}}{\text{Utilisation efficiency as a decimal} \times \text{Lumens per lamp}} = \text{Number of lamps.}$$

This is an example of the simple problem, but the calculation for side walls and more complicated cases may be worked out in a similar way.

Use of the Lumen in Evaluating Polar Curves of Light Distribution.

A very interesting application of the Lumen arises in connection with the interpretation of polar curves of light distribution in candlepower. Such curves are necessary and useful for showing how the flux of light from a lamp, either alone or in combination with a suitable globe or reflector, varies in different directions. The adoption of rating in Lumens does not imply that these curves can be dispensed with, but on the contrary is an aid in their interpretation. The candlepower distribution curve merely expresses the variation in intensity in a given plane, but gives no immediate conception of the

* I say generally because candlepower-values will still be used to express intensity in different directions. Because we recognise that pressure is not a satisfactory basis of comparing the capacity of pumps, it does not follow that the pressure in pumps should not be studied and stated.

volume of light in the total flux, *i.e.*, the "shower of light" from the source investigated. We have already seen in Figs. 7, 8, and 9 how confusing such curves may be if applied to compare the total flux of light from different sources. The true basis of comparison only becomes apparent when we employ the Rousseau curve or similar trigonometrical constructions and measure up the resulting diagram with a planimeter; whereas if sheets giving the values of the Lumens in each zone are presented we have a proper means of comparing not only the total flux of light in each case, but the true proportions of this flux emitted over different angles.

Fig. 14 shows such a photometric record sheet of a reflector and lamp, with values of light flux as expressed in Lumens. A curve of light distribution for this unit is given in Fig. 13. A study of this clearly shows the very definite and complete expression of luminous output for the various zones beneath the lamp, which permits of accurate comparisons between different reflectors and light distribution curves. As an instance of this, we have in Figs. 13 and 15, with their corresponding tables shown in Figs. 14 and 16, two reflectors giving entirely different distribution curves from the same size of lamp—100 watts. These comparisons are further complicated by the curves being drawn to different scales. The Lumen values, however, as shown in the tables for each reflector, present an exact comparison for each and every angular position and zone and show that the apparent difference which appears to the eye by comparison of the two curves does not really exist in actual light flux.

The table in Fig. 17 presents a list of standard vacuum type and half-watt type metal filament lamps, and gives the efficiencies at present supplied in Great Britain. For the vacuum type lamps, it is given on the present basis—watts per candle, and on the new basis Lumens per watt. For the half-watt type lamps, the efficiency is given on the new basis only—Lumens per watt. The half-watt type lamp has a much higher reduction factor of horizontal to total spherical candlepower than the ordinary vacuum type lamp, so that the half-watt type lamp gives considerably greater total flux of light with the same horizontal candlepower than the vacuum type lamp does. This emphasises the use of the Lumen rating and Lumen per watt efficiency basis for the half-watt type lamp. This table also gives full Lumen values for each size of lamp, and the corresponding Lumen values at various utilisation efficiencies as shown.

It has been argued that the Lumen values are invariably derived from the measurement of candlepower in practice; even were this the case it would not prejudice the Lumen as a method of presenting illuminating power, but as a matter of fact it is also possible to make measurements direct in Lumens.

Electric lamps are now most satisfactorily and readily photometered by the use of the sphere photometer. The use of this form of photometer is rapidly growing, and simplifies the problem of measuring the total flux of light from an illuminant.

The lamp is inserted in the centre of an enclosing sphere, and the total light flux given out by the lamp is measured in one reading. This reading can be directly measured in Lumens without having recourse to candlepower values.

It is, however, convenient and natural to convert candlepower values into Lumen values as results are at present almost invariably available in terms of candlepower. The ordinary metal filament (vacuum type) lamp gives a Lumen value about ten times its candlepower (mean horizontal) value. This, a 16 c.p. lamp, gives 160 Lumens, a 100 c.p. lamp, 1000 Lumens, &c.*

I have advocated the adoption of the Lumen and supported its case solely on its merits, and I firmly believe that these merits will prevail and ultimately establish this unit in practice. I have not referred to the endorsement of the Lumen in other countries, but it is interesting to know that it has received the endorse-

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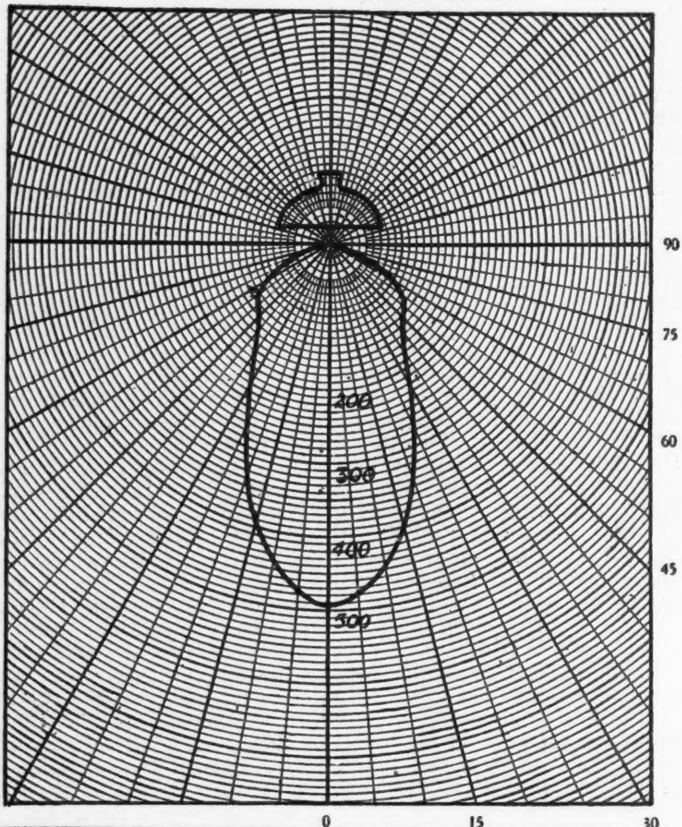
* This ratio of 10 between the value in Lumens and the mean horizontal candlepower is derived as follows :—

The mean spherical candlepower of the ordinary vacuum metal filament lamp is 78 per cent. to 79 per cent. of the mean horizontal candlepower. Therefore the flux in Lumens is $12{\cdot}57 \times 0{\cdot}79 = 9{\cdot}94$, or practically ten times the mean horizontal candlepower.

Reflector No. 710

Photometric Curve Sheet



NOTE—When 1 division equals 1 Cp. one inch equals 20 lumens, measured as horizontal distance from nadir to center of 10 degree zones.

Angle	Candle Power: Lamp & Refl.	Candle Power: Bare Lamp	Angle	Candle Power: Lamp & Refl	Candle Power: Bare Lamp
0°	492.0		90°		
5°	478.0		95°		
15°	893.0		105°		
25°	278.0		115°		
35°	183.3		125°		
40°			135°		
45°	141.0		145°		
55°	122.0		155°		
65°	67.3		165°		
75°	12.6		175°		
85°	4.3		180°		

	Lamp and Reflector			Bare Lamp		
Zone . . .	0-60°	0-90°	0-180°	0-60°	0-90°	0-180°
Lumens . .	617.3	702.0				866.0

Reflector X-Ray N° 710 Holder Form "O".

Lamp Mozda Clear S-30-A Watts 100.0 Volts 110.0

Plotted by [signature] Test No. DW-1

National X-Ray Reflector Co.
Engineering Department
CHICAGO

W.P.C. 1.13

Date Sept. 1 1913.

FIG. 13.—Photometric Curve Sheet (Light Distribution Curve) of Lamp and Reflector.

To be used with Photometric Record Sheet (Fig. 14), showing how Lumen values are employed for such curves to evaluate clearly and accurately the light flux in each section or angular zone of the curve, and thus enable accurate comparisons to be made with any other distribution curve, such as that shown in Fig. 15 (and Record Sheet, Fig. 16).

Reflector No. 710

Photometric Record Sheet

Reflector X-RAY NO. 710 Holder $2\frac{1}{4}$" form O

Lamp Mozda-clear S-30-A Watts 100.0 Volts 110.0

Calculated by [illegible] Test No. DW-1

LIGHT FLUX DELIVERED

ZONE	MID-ZONE Angle	MID-ZONE C P	Lumen Constant	Lumens	ZONE	Lumens	Per Cent of Bare Lamp Flux
0 - 10°	5°	478.0	.0954	45.5	0 - 10°	45.5	5.3
10°- 20°	15°	393.0	.2834	111.2	0 - 20°	156.7	18.1
20°- 30°	25°	275.0	.4630	127.2	0 - 30°	283.9	32.8
30°- 40°	35°	183.3	.6280	115.0	0 - 40°	398.9	46.0
40°- 50°	45°	141.0	.7740	109.0	0 - 50°	507.9	58.6
50°- 60°	55°	122.0	.8970	109.4	0 - 60°	617.3	71.3
60°- 70°	65°	67.3	.9920	66.7	0 - 70°	684.0	79.0
70°- 80°	75°	12.6	1.0580	13.3	0 - 80°	697.3	80.5
80°- 90°	85°	4.3	1.0910	4.7	0 - 90°	702.0	81.1
90°-100°	95°		1.0910		0 - 100°		
100°-110°	105°		1.0580		0 - 110°		
110°-120°	115°		.9920		0 - 120°		
120°-130°	125°		.8970		0 - 130°		
130°-140°	135°		.7740		0 - 140°		
140°-150°	145°		.6280		0 - 150°		
150°-160°	155°		.4630		0 - 160°		
160°-170°	165°		.2834		0 - 170°		
170°-180°	175°		.0954		0 - 180°		
					60°- 90°		
					90°- 120°		
					120°- 180°		

Total Lumens of Bare Lamp 866.0

Total Lumens of Lamp with Reflector 702.0

Efficiency 81.1

Note—Lumens = Lumen Constant X Candle Power

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National X-Ray Reflector Co.
Engineering Department
CHICAGO

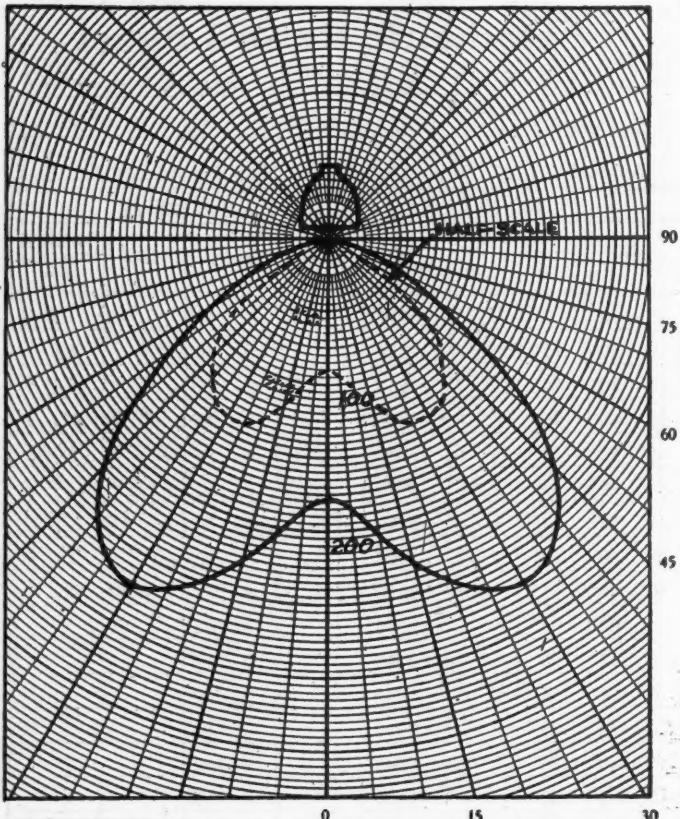
Date Sept 1st 1913.

FIG. 14.—Table of Values, showing how Lumens are employed to express accurately the light flux delivered in each section or angular zone of the light distribution curve of lamp and reflector (Fig. 13).

C

Reflector No. 565.

Photometric Curve Sheet



NOTE—When 1 division equals 1 Cp. one inch equals 20 lumens; measured as horizontal distance from nadir to center of 10 degree zones

Angle	Candle Power: Lamp & Refl.	Candle Power: Bare Lamp	Angle	Candle Power: Lamp & Refl.	Candle Power: Bare Lamp
0°	177		90°		
5°	186		95°		
15°	230		105°		
25°	264		115°		
35°	266		125°		
40°			135°		
45°	222		145°		
55°	132		155°		
65°	58.5		165°		
75°	23.3		175°		
85°			180°		

	Lamp and Reflector			Bare Lamp		
Zone . . .	0-60°	0-90°	0-180°	0-60°	0-90°	0-180°
Lumens . .	662	745	745			971

Reflector X-Ray No. 565. 3-30-A Holder 2¼" Form "H".

Lamp Clear Mazda Watts 100.0 Volts 110.0

Plotted by [signature] Test No. G-1.

National X-Ray Reflector Co.
Engineering Department
CHICAGO

W.P.C -1.02

Date Feb. 1, 1914.

FIG. 15.—Photometric Curve Sheet (Light Distribution Curve of Lamp and Reflector. (Dotted curve same scale as curve in Fig. 13).

To be used with Photometric Record Sheet (Fig. 16), showing how Lumen Values are employed for such curves to evaluate clearly and accurately the light flux in each section or angular zone, and enable definite comparisons to be made with ther distribution curves, such as Fig. 13 (and Record Sheet Fig. 14).

Reflector No. 565

Photometric Record Sheet

Reflector X-RAY No. 565 Holder $2\frac{1}{4}$" form H

Lamp Mazda-Clear 5-30-A Watts 100.0 Volts 110.0

Calculated by J. A. H. Test No. G-1

LIGHT FLUX DELIVERED

ZONE	MID-ZONE Angle	MID-ZONE C P.	Lumen Constant	Lumens	ZONE	Lumens	Per Cent of Bare Lamp Flux
0 - 10°	5°	186.0	.0954	17.7	0 - 10°	17.7	1.8
10°- 20°	15°	230.0	.2834	65.1	0 - 20°	82.8	8.5
20°- 30°	25°	264.0	.4630	122.2	0 - 30°	205.0	21.1
30°- 40°	35°	266.0	.6280	167.0	0 - 40°	372.0	38.6
40°- 50°	45°	222.0	.7740	172.0	0 - 50°	544.0	56.0
50°- 60°	55°	132.0	.8970	118.0	0 - 60°	662.0	68.1
60°- 70°	65°	58.5	.9920	58.0	0 - 70°	720.0	74.1
70°- 80°	75°	23.3	1.0580	25.0	0 - 80°	745.0	76.7
80°- 90°	85°		1.0910		0 - 90°		
90°-100°	95°		1.0910		0 - 100°		
100°-110°	105°		1.0580		0 - 110		
110°-120°	115°		.9920		0 - 120°		
120°-130°	125°		.8970		0 - 130°		
130°-140°	135°		.7740		0 - 140°		
140°-150°	145°		.6280		0 - 150°		
150°-160°	155°		.4630		0 - 160°		
160°-170°	165°		.2834		0 - 170°		
170°-180°	175°		.0954		0 - 180°		
					60°- 90°		
					90°- 120°		
					120°- 180°		

Total Lumens of Bare Lamp 971.0

Total Lumens of Lamp with Reflector 745.0

Efficiency 76.7

Note—Lumens = Lumen Constant X Candle Power

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National X-Ray Reflector Co.
Engineering Department
CHICAGO

Date Feb. 1st 1914.

FIG. 16.—Table of Values, showing how Lumens are employed to express accurately the light flux delivered in each section or angular zone of the light distribution curve of Lamp and Reflector (Fig. 15).

FIUGRE 17.

LUMEN DATA FOR METAL FILAMENT (TUNGSTEN) LAMPS, OF SIZES AND EFFICIENCY STANDARDS IN GREAT BRITAIN, JANUARY, 1917. VOLTAGE CLASS, 100 – 130.

	Size of Lamp in Total Watts	Efficiency		Initial Lumen Values at various Utilisation Efficiencies.																
		Watts per Mean Horiz C.P.	Lumens per Watt	Total 1.00	0.65	0.60	0.55	0.50	0.45	0.40	0.36	0·34	0·32	0.30	0.28	0.26	0.24	0 22	0.20	0.15
Vacuum type	20	1·20	8·1	163	105·9	97 8	89·6	81·5	73·3	65·2	58·6	55·4	52·1	48·9	45·6	42·3	39·1	35·8	32·6	24·4
	30	1 15	8·5	255	165.7	153	140·2	127·5	114·7	102	91·8	86·7	81·6	76·5	71·4	66·3	61·2	56·1	51·0	38·2
	40	1·15	8·4	341	221·6	204·6	187·5	170·5	153·4	136·4	122·7	115·9	109·1	102 3	95·4	88·6	81·8	75·0	68·2	51·1
	60	1·10	8·9	535	347.7	321	294·2	267·5	240 7	214	192·6	181·9	171·2	160·5	149·8	139 1	128 4	117·7	107	80·0
	100	1·05	9·3	930	604·5	558	511·5	465	418·5	372	334·8	316·2	297·6	279	260·4	241·8	223·2	204·6	186	139·5
	150	1·0	9·8	1470	955·5	882	808·5	735	661·5	588	529·2	499·8	470·4	441	411·6	382·2	352·8	323·4	294	220·5
Half-Watt type	100	—	12·5	1250	812·5	750	687·5	625	562·5	500	450	425	400	375	350	325	300	275	250	187·5
	150	—	13·4	2010	1306·5	1206	1105·5	1005	904·5	804	723·6	683·4	643·2	603	562·8	522·6	482·4	442·2	402	301·5
	200	—	14·0	2795	1816·7	1677	1537·2	1397·5	1257·7	1118	1006·2	950·3	894·4	838·5	782·6	726·7	670·8	614·9	559	419·2
	300	—	15·3	4600	2990	2760	2530	2300	2070	1840	1656	1564	1472	1380	1288	1196	1104	1012	920	690
	500	—	16·12	8060	5239	4836	4433	4030	3627	3224	2901·6	2740 4	2579·2	2418	2256·8	2095·6	1934·4	1773·2	1612	1209
	1000	—	18·0	18000	11700	10800	9900	9000	8100	7200	6480	6120	5760	5400	5040	4680	4320	3960	3600	2700
	1500	—	18·0	27000	17550	16200	14850	13500	12150	10800	9720	9180	8640	8100	7560	7020	6480	5940	5400	4050

ment of the American Illuminating Engineering Society, of the Association of the Edison Illuminating Companies and of the National Electric Light Association, is being employed in regular practice in the rating of electric lamps. The Lumen of is Continental origin, and was originally proposed by Prof. Blondel, of Paris.

In view of the Lumen's merits as an all-round term for lighting practice, and the general situation as described herein, the writer hopes that all manufacturers of lamps and lighting appliances, supply companies, both gas and electric, and all those having to do with light and illumination in Great Britain, will co-operate to assist in the inttroducion and popularisation of the Lumen.

This programme would, for the time being, simply follow the plan of the principal electric lamp manufacturers mentioned above, of stating in addition to the candlepower values the values of their lamps in Lumens. No better work could be undertaken by this Society than assisting to this same end, particularly in preparing and publishing a monograph or pamphlet describing the Lumen in clear, popular language, and illustrating by numerous examples its meaning, its value, and its application to practical lighting problems in various ways.

DISCUSSION.

The CHAIRMAN, in opening the discussion, referred to the need for a good and brief definition of the Lumen.

Mr. S. H. CALLOW : I do not think I can add very much to the remarks of Professor Morris and Mr. Willcox ; but I feel strongly that the old method of rating illuminants by horizontal candlepower is inadequate to meet present-day conditions. The rating of electric lamps by horizontal candlepower dates from the early days of carbon filament lamps, when all filaments were practically uniform in shape, and the maximum candlepower was given in horizontal direction.

This is not so to-day, either in the case of many forms of electric units or gas units ; and therefore the rating of such units in horizontal candlepower does not give an adequate comparison of one form of unit with another. After all is said and done, when a consumer purchases any form of illuminant, the most important point is the total quantity of light he is going to obtain from it, and not the maximum candlepower which it may give at one particular angle.

The present method of rating also lends itself to deception. For instance, it is obviously quite easy to design a vacuum type metal filament lamp which will give a candlepower equal to twice the value of the watts consumed in one given direction. Such a lamp might then be called a " half watt " lamp, although not gas filled, and having an efficiency in watts per mean spherical candlepower only equal to that of the ordinary vacuum type lamp. Such lamps have in the past been foisted on the public as " half watt " type lamps. If they had been rated in spherical candlepower or Lumens this could not have been done.

I think it is therefore fairly obvious that a change in rating is not only desirable, but necessary. If we are to take one step from horizontal to mean spherical candlepower I think it preferable to take two, and pass on to rating in Lumens, which is the most convenient unit.

Mr. J. G. CLARK, speaking from the gas standpoint, said that he would like to testify to the usefulness of the Lumen from the practical point of view, but he was a little bit uneasy about its general adoption as a commercial unit.

The rating of lamps resolved itself into two portions, the scientific and the commercial. The former hardly needed our present attention, but some speakers seemed to have the impression that the luminous value of a lamp in Lumens was easily obtainable by simply putting it in an Ulbricht sphere and getting the figure directly.

This, however, ignored distribution entirely, and if we did anything to hide the effect of distribution we should be in a bigger hole than ever. It was very nice to have in a single figure the total amount

of light marked on a lamp, but if we did not know where the light was going this was not a very exact guide as to the best form of lamp to be used. For instance there might be two forms of lamps, each with the same flux of light in Lumens but one of them might give 60 per cent. of its light in an upward direction and 40 per cent. in a downward direction whilst the other might give the reverse. In all direct lighting systems practically all the light was delivered on the downward direction by the aid of reflectors, and as all these latter were not of the same efficiency this fact introduced the complication that two lamps of the same indicated efficiency in Lumens were not equal when fitted with globes and reflectors. Of two lamps the one which gave the greater quantity of light in the downward direction and the least to the reflector would show up to the best advantage, and in this way the Lumen might be a little misleading. Professor Morris had pointed out that to make the best use of the Lumen we should have to specify Lumen values in specific zones, but this brought us back again to the distribution curve, because in order to get zonal values it would be necessary to get the polar curve of the lamp and practically it did not take us very much further than we are now.

On the whole he could not help feeling that the use of the term Lumen was just as likely to be unsatisfactory as the terms we already had, and, after all, lighting problems seemed to be in need of a good deal of education of the general public. If the Council could, through the educational institutions, make lighting as a practical problem a more general subject of study the question would solve itself, because no man who knew anything about lighting would be deceived by polar curves which seemed to have a bigger radius in one direction than another.

Mr. A. Blok said that if it was, in the opinion of the meeting desirable, that the Lumen should be adopted as a basis for rating lamps, the Society must not rest content until it had made the term intelligible to the people concerned. The substitution of a new unit for an existing one was a big undertaking and it was necessary to show a clear case for it. The paper presented before the Society by Mr. Clinton in March, 1914,* showed what a reliable and powerful tool the Lumen was to illuminating engineers, and if the Society, after the present discussion, decided that its adoption was a desirable thing, then he hoped that the Council would consider Mr. Willcox's suggestion of setting up some proper machinery for disseminating what might be called "lumen knowledge." An obvious course would be for the Society, as a neutral platform, to draw up a pamphlet in simple terms containing a number of worked-out examples which would be of use at any rate to the average contractor, if not to the ordinary users of lamps. The average contractor would probably be puzzled if the lamps were marked in Lumens unless he were clearly told what the Lumen is, and the wide distribution of a simple explanatory pamphlet bearing the stamp of authority of the Society would do a great deal towards establishing the Lumen in the lighting industry. Without a definite campaign of this sort he thought that there was little chance of much good being done.

Dr. L. Rabinovitch, while recognising the advantages of the Lumen from a scientific standpoint, thought that the larger values it implied would be a source of confusion to the general public, and that the great variations in the distribution of light due to various shades and reflectors would make explanation difficult.

It appeared to him, as a lamp maker, that while the measurement of horizontal candlepower was an easy process, the determination and guarantee of a definite number of Lumens would be a more complicated process.

Would it not be possible to find a compromise between the two methods of rating by providing fuller information regarding the candlepower in different directions? Dr. Fleming had demonstrated that in order to convert mean horizontal candlepower into mean spherical candlepower a coefficient of 0·78 was necessary in the case of carbon filament lamps and a somewhat different figure in the case of ordinary tungsten lamps with straight filaments (which

* *Illum. Eng.*, Vol. VII., p. 189, April 1914.

formed much the larger proportion of lamps manufactured). If lamp makers would make a practice of mentioning such coefficients in their catalogues he thought this would go far to satisfy the needs of the illuminating engineer.

Mr. G. CAMPBELL supported the use of the Lumen and expressed regret that Mr. Clark did not appear to be in full agreement with the proposition, because it would be a good thing if representatives of gas and electric lighting could come to a common understanding on this matter.

The present was a good opportunity for making the change which might not occur again. He had never found it very difficult to explain the use of the Lumen, but the suggestion that the Society should help the movement was most important. Without that support the discussion would be of relatively little value. If the members of the Tungsten Lamp Association would agree to mark their lamps in Lumens and Watts, this would be a very considerable step forward.

Mr. E. STROUD: From the discussion many of the previous speakers seem to imply that if the Lumen were adopted as a unit it would no longer be necessary to consider candlepower in a given direction, polar curves, illumination curves and all calculations necessary for illumination problems. This, of course, is entirely fallacious, as one would still have to consider all these factors, there being no such simple way out of a subject which requires careful and long study.

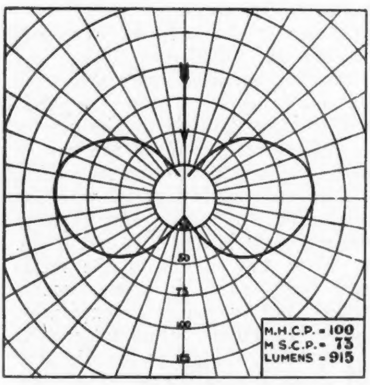
I understand that the real question before us to-night is to discuss the Lumen as a desirable rating for lamps.

The present rating, as generally meant, is in terms of horizontal candlepower, but this is by no means standard, some makers rate by the maximum candlepower whatever the direction, and some even rate lamps at the maximum candlepower when equipped with reflectors.

The resultant illumination does not depend upon the rated candlepower, but depends upon the equipment of the installation.

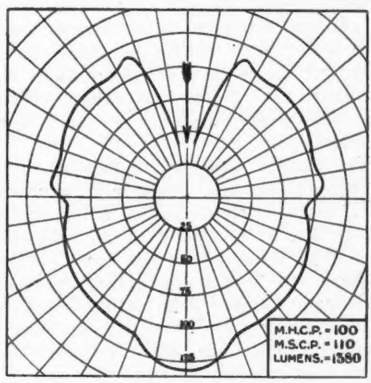
It is possible to obtain as much or more illumination for a specific purpose, with a 25 c.p. lamp properly equipped than with a 100 c.p. lamp badly employed.

Therefore, regarding the correct rating of lamps, I should like you to consider the purpose for which the output rating is of use.



STRAIGHT FILAMENT TUNGSTEN LAMP, PLOTTED TO M H.C.P.=100.

FIG. 1.



HELICAL FILAMENT TUNGSTEN LAMP, PLOTTED TO M.H.C.P.=100.

E. STROUD, JAN. 1917.

FIG. 2.

The output rating is required:—

First.—To obtain the efficiency.

Second.—For the purpose of comparing one lamp with another.

Thirdly.—To give the lighting engineer the *quantity* of light at his disposal.

For each of these purposes it is necessary to know the quantity of light emitted.

To show how inadequate is the rating

by mean horizontal candlepower, I would refer to Figs. 1 and 2.

Figure 1 shows the polar distribution curve of an ordinary straight filament tungsten lamp plotted to m.h.c.p. of 100 c.p.

Figure 2 shows the polar distribution curve of a tungsten lamp with the helical form of filament winding, also plotted to m.h.c.p. of 100 c.p.

The quantity of light or Lumens in the first case are 913, while in the second 1380, *i.e.*, 50 per cent. more light is given by Fig. 2 than Fig. 1, and yet under the old basis these lamps would be rated as equal, *i.e.*, 100 c.p.

One might nearly forgive the maker of the lamp with the helical form of winding so as to justify his goods, if he called it 130 c.p., being the maximum in a downward direction, but where does this lead us? Can we call a 50 c.p. lamp 500 because we equip it with a reflector which concentrates the light to this extent?

Undoubtedly the quantity rating must be adopted sooner or later, and so long as it is not adopted and standardised, so long will the science of illumination be retarded, and doubts be raised as to the exact meaning of a particular specification.

The Lumen rating overcomes all this, it tells exactly how much light is given by a source, irrespective of distribution, which cannot be easily misrepresented.

It then remains for the illuminating engineer to utilise the light available with such equipment as would be most advantageous, so as to obtain the maximum of effect or efficiency for the particular problem in view.

It has been suggested that the total Lumens given by a source is too large a quantity, being 12·57 times the mean spherical candlepower, and likely to cause confusion

On this point I would like to make a suggestion. A 100 m.h.c.p. lamp roughly gives 1000 Lumens. If we had a unit which might be called a "Large Lumen," or "Deka Lumen," which was equal to 10 Lumens, then the change could be effective without undue trouble as the lamp with the old 100 c.p. rating would now be 100 Lumens and the new improved lamps would show their improvement as they deserve.

Communicated:—Mr. Trotter raised the query as to simple definition of the Lumen, As this is rather difficult to define in simple language would it not be better to show at this stage how easy it is to obtain the effective Lumens in a practical case—

Lumens=Foot-candles × sq. ft.?

Therefore, if we have an everage intensity of 3 foot-candles in an area of 100 sq. ft., we have 300 Lumens over that area, from which the efficiency of the installation can easily be derived.

Mr. A. Wise said that it was generally agreed that the misuse of the term "candlepower" necessitated the enforcement of a common basis of comparison between various sources of light. At the same time he felt doubtful whether the adoption of the Lumen, although a useful unit in the hands of the illuminating engineer, would remove such possibilities of misconception.

If the output of a lamp was expressed in Lumens this would give a large and somewhat inconvenient figure and some time would be necessary before the public learned to appreciate the significance of these higher values. When the carbon filament lamp was first put on the market the public were made familiar with the conception of candlepower and adjusted their minds to the idea of 8, 16 and 32 c.p. units. With the advent of the metal filament lamp rating in watts became customary, but even now a considerable section of the public hardly understood what they were calling for when demanding 20, 30 or 40 watt lamps. The introduction of the Lumen would involve yet another change, as people would have to accustom themselves to figures of the order of hundreds and even thousands. If, on the other hand, the value of a lamp were expressed in mean spherical candlepower, anyone desiring to work in Lumens could easily make the conversion by multiplying the necessary factor.

In order to illustrate the distribution of light from lamps it would be necessary to tabulate the Lumens in different zones. Such a table would serve essentially the same purpose as the polar curve, except that it would probably only give figures at intervals of 10 or 15 degrees.

In any case he thought there was a need for a clear definition of the Lumen. In Mr. Willcox's paper several distinct definitions were given and these explanations, while all of them correct, might lead to confusion at first sight.

Mr. C. H. PITMAN thought that while it was difficult to show the light in different directions without a polar curve, for the ordinary public such a curve was not necessary. If the lamp lists gave figures of total Lumens and Lumens per zone and the fittings lists gave conversion figures for particular forms of reflectors it could be ascertained what was the amount of light in the useful direction from the combined lamp and reflector.

The conversion figures would be based on the efficiency of the reflector. Thus a 60-watt lamp giving 490 Lumens used with a distributing reflector having an efficiency of 80 per cent. and having an angle of spread of 126 degrees, would give approximately 390 Lumens in this zone. With regard to evenness of illumination this could always be shown by an illumination curve.

It was in connection with lamps which gave their maximum light at particular angles that the adoption of the Lumen would be of the greatest service, for the buyer would know immediately which was the lamp that best suited his requirements.

Whilst Mr. Stroud's suggestion of bringing the number of Lumens down to a smaller figure by dividing by 10, and using a larger Lumen unit, deserved consideration he thought that a better proposal would be to rate lamps in Lumens per watt, thus arriving at a smaller figure, from which all other terms could be quickly derived.

Mr. J. S. DOW said that since the first discussion on this subject in 1914 he had always felt that, from the scientific standpoint, the Lumen was the best term to adopt, and Mr. Willcox had put the case extremely well. The only question was how far it was practicable to make the ordinary public accept it. The onus of doing so rested largely on the makers of lamps and lighting appliances, and no doubt a little bulletin on the lines suggested would be the first step in the necessary educational campaign. Mr. Willcox and Prof. Morris were right in suggesting that the confusion and misrepresentation arising from statements of the effective light in one direction only were really facilitating by rating in candlepower. A man who produced a lamp in which the light was concentrated mainly in one direction and gave the impression that this was a proper measure of the illuminating power of the lamp as a whole was certainly guilty of misrepresentation; because in the data presented there was no clear indication to the public of the area over which this high local candlepower operated nor of the proportion which this formed of the whole output of light. The series of curves shown by Mr. Willcox demonstrated very clearly how the impression conveyed to the uninitiated by polar curves of candlepower might be quite misleading. Such curves are useful in the hands of the expert and will continue to be so, but the man in the street, to whom the Rousseau construction is unintelligible, is very apt to misinterpret them.

Now when the illuminating powers are tabulated in terms of Lumens the value given for any particular zone takes into account the area over which the candlepower is emitted. The added values in each zone give the total flux of light and the proportion of light concentrated at different angles is made evident. In these circumstances it might be quite legitimate to point out that with a certain form of lighting unit a larger proportion of light was directed in a useful direction; at all events the scope for misrepresentation was much less.

Mr. Dow also pointed out that the conception of the Lumen was essential to many calculations with beams of light, such as those emitted from searchlights and projection apparatus. It was only by comparing the flux of light received by a cinematograph screen with the output of the arc in Lumens that the inefficiency of the ordinary projecting lantern could be demonstrated. Similarly, in view of the different degrees of dispersion met with in forms of searchlights, using respectively arcs, oxy-acetylene, or electric incandescent coiled filaments, such apparatus should not be

rated in max. candlepower alone. This was undoubtedly a very important, —perhaps the most important—factor. But the light yielded at angles slightly outside the angle of max. c.p. was also of importance. The beam from a searchlight being circular in section the flux of light could readily be obtained experimentally by dividing the section of the beam into concentric annuli, multiplying the area of each successive portion by the corresponding illumination thereon, and adding up the products.

Mr. L. GASTER said the thanks of the Society were due to Professor Morris for having undertaken to open the discussion at somewhat short notice, and to Mr. Willcox for the very useful explanatory matter which he had provided in his contribution.

The question of the best method of specifying the illuminating value of lamps had been raised at several meetings of the Society. Since then the proposition that lamps should be rated in Lumens had been officially endorsed at the Convention of the American Illuminating Engineering Society, in which both the electric and gas interests are strongly represented. This decision made it necessary to re-open the subject, and the whole matter was one of great future importance in relation to the international consideration of methods of rating lamps. As such it would no doubt receive the attention of the National Illumination Commission in due course.

It appeared that the leading lamp makers and manufacturers of shades and reflectors in this country were favourably considering the proposal. There had been unquestionably a great deal of looseness in the methods of stating candlepower of lamps hitherto adopted, and if the new method would bring about greater uniformity and accuracy it would be welcome. Naturally, as Mr. Willcox had said, a good deal of educational work would be necessary to make the term familiar, and the Illuminating Engineering Society would gladly co-operate with lamp makers in producing a pamphlet explaining the use of the Lumen for rating lamps, and its value in illuminating engineering calculations. Such a pamphlet was very necessary in the interests of the general public, and if rating in Lumens became general it would provide a proper basis on which they could judge the importance of each new improvement in illuminants as it occurred.

The CHAIRMAN, in summing up the discussion, said that he had taken part in a great controversy about the Lumen and its relation to candlepower in May, 1914,* and he had been regarded as an old-fashioned conservative heretic. But that discussion was of a philosophical nature and his main contention resembled the theorem of the egg and the hen—which came first?

He had clearly stated that he neither disparaged the Lumen as a theoretical quantity† nor under-rated it as a practical unit. Prof. A. Blondel has, in the Lumen, given invaluable assistance to those engineers who have to make calculations. Two or three definitions of the Lumen had been proposed during the discussion, but he had not seen one which made him happy. He wanted a definition for the man in the street. If such a man were told that the 16 horizontal candlepower is going to be called 158 Lumens, he will think there is a catch and that he is going to be "had."

The lamp trade had settled that they were going to rate their lamps in Lumens. They were all entirely in the hands of the lamp trade as those who have to use continuous current at the higher voltages know to their cost. Still he would like to find a popular definition and a plausible excuse for this rating, not so much to assist the lamp makers as to help those members of the Illuminating Engineering Society who would certainly be called upon to explain what it was all about.

Mr. F. W. WILLCOX, in reply, stated that many of the questions in the discussion were answered in his paper which he regretted through lack of time he could not read in full. He would therefore refer all interested in the discussion to the full paper and diagrams accompanying same, requesting that it be studied in its entirety, when he ventured

* *Illum. Eng.*, Vol. VII., pp. 339, *et seq.*

† *Lot. cit.* p. 35.

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to hope that many of the objections and the queries raised would be satisfactorily answered.

He noted particularly in the case of Mr. Wise's comments that his points of objection arose out of a misunderstanding of the nature of the Lumen. The value of the Lumen is not affected by the unit of distance.

He was particularly interested in the difficulties Mr. Clark referred to in connection with candlepower distribution curves. This whole question was very fully covered in the paper, and Mr. Clark's fears and objections quite fully replied to. Contrary to the views expressed by Mr Clark, the Lumen values, once established, would ensure more than ever the provision of complete data for all forms of light distribution. Results would be much more convenient and intelligible when the lighting values for various sections (zones) of the distribution curve are expressed in Lumens which can be added together or subtracted to give the total Lumens in any way desired. The Lumen would therefore provide a definite means of comparing the total amount of light given by different lamps with different reflectors, and would simplify and help to evaluate the candlepower distribution curves in a way that was not possible with candlepower values.

He sincerely hoped that representatives of gas would find it possible to fall in with the idea of the Lumen. Surely such a unit by reason of its obvious advantages would be a desirable one for all forms of lamps and every branch of the lighting industry, gas as well as electric.

As regards the suggestion of Mr. Stroud for the adoption of a Lumen value 10 times greater, to be known as the large Lumen or "Deka-lumen," this suggestion seems a desirable one on first thought, but further consideration shows it is not so. The larger numerical value the Lumen value provides is valuable, in that it permits a more accurate expression of efficiencies than would be possible with a smaller unit such as the candle power. It is well known that the common expression for efficiency for electric lamps "watts per candle" is really the inverse of the proper efficiency expression, which

should be "candles per watt." The watts per candle expression, however, was adopted simply because the candles per watt was, for electric lamps, always a fraction, whereas watts per candle gave a whole number and was thus preferred. By retaining, therefore, the full numerical quantity of the straight Lumen, we have a full numbered (instead of a fractional) value, which permits accurate expression for efficiencies in the term "Lumens per watt."

As an example of this, let us take the 30 watt 200 volt vacuum type tungsten filament lamp, whose total Lumens is 229, giving an efficiency of 7·63 Lumens per watt. If the large Lumen idea was adopted, this would result in our having 22·9 large Lumen for the Lumen value and the Lumens per watt would be a fraction, namely, 0·763.

As to the simple definition of the Lumen which Mr. Trotter desires, I have endeavoured in my paper to give this, and at the same time to enlarge the idea of the Lumen by a somewhat lengthened description, so as to present the conception in various ways. It would be wrong to infer because some place is thus given to the definition of the Lumen that there is any question as to the Lumen being a term of precise meaning and having an exact value. It will naturally depend upon the unit of candlepower adopted, but as the international unit of candlepower is now generally (with the exception of Germany) adopted, this fixes the value of the Lumen absolutely.

In the opinion of the speaker, the simplest definition of the Lumen is to state that it is the amount of light that gives an illumination of 1 foot candle on 1 square foot of area. This is the definition that has been employed in lamp publications recently issued by the writer.

Professor J. T. MORRIS, in reply, said that he regarded the suggestion that the Society should issue a pamphlet as a most valuable one. In the first place it would clear the minds of those who wrote the pamphlet, and then it would be very helpful to those who had to handle practical illumination problems. The suggestion had also been made that lamps might be most useful to scientific people as well as to those who wanted to know the real efficiency of the lamp, and it was a suggestion he would support very strongly.

Communicated :—Dr. Rabinovitch's suggestion to use the Fleming factor, *i.e.*, the factor by which to multiply the horizontal candlepower in order to obtain the M.S.C.P. is quite sound so long as no spiralised filaments are used: but now that half watt lamps have come to stay, and others with similar arrangements of filaments, sometimes permanently combined with reflectors, it is practically useless.

I cordially support Mr. Clark's suggestion that more time might be devoted at some at least of our educational institutions to practical problems in connection with illumination.

Summing up, it appears that one speaker is rather against the practical use of the Lumen, three are more or less open to conviction, and the remainder, eight in number, are definitely in favour of its use in practical work.

In particular Mr. Willcox, Mr. Dow and Mr. Stroud make out good cases in support of the change. Under the circumstances I consider that a clear case has been made out for the Illuminating Engineering Society to take the necessary steps to assist in the proposed reform.

[We are holding over to our next number special contributions from Mr. A. P. Trotter and others dealing with the definition and use of the Lumen.—ED.]

OBITUARY.

We learn with regret of the death of two valued Corresponding Members of the Society, Prof. S. A. Rumi, of Genoa, and Prof. Dr. Friedrich Erismann, of Zurich. Prof. Rumi was keenly interested in photometric problems, and Prof. Erismann a well-known authority on natural school lighting. A fuller note on this subject will appear in due course.